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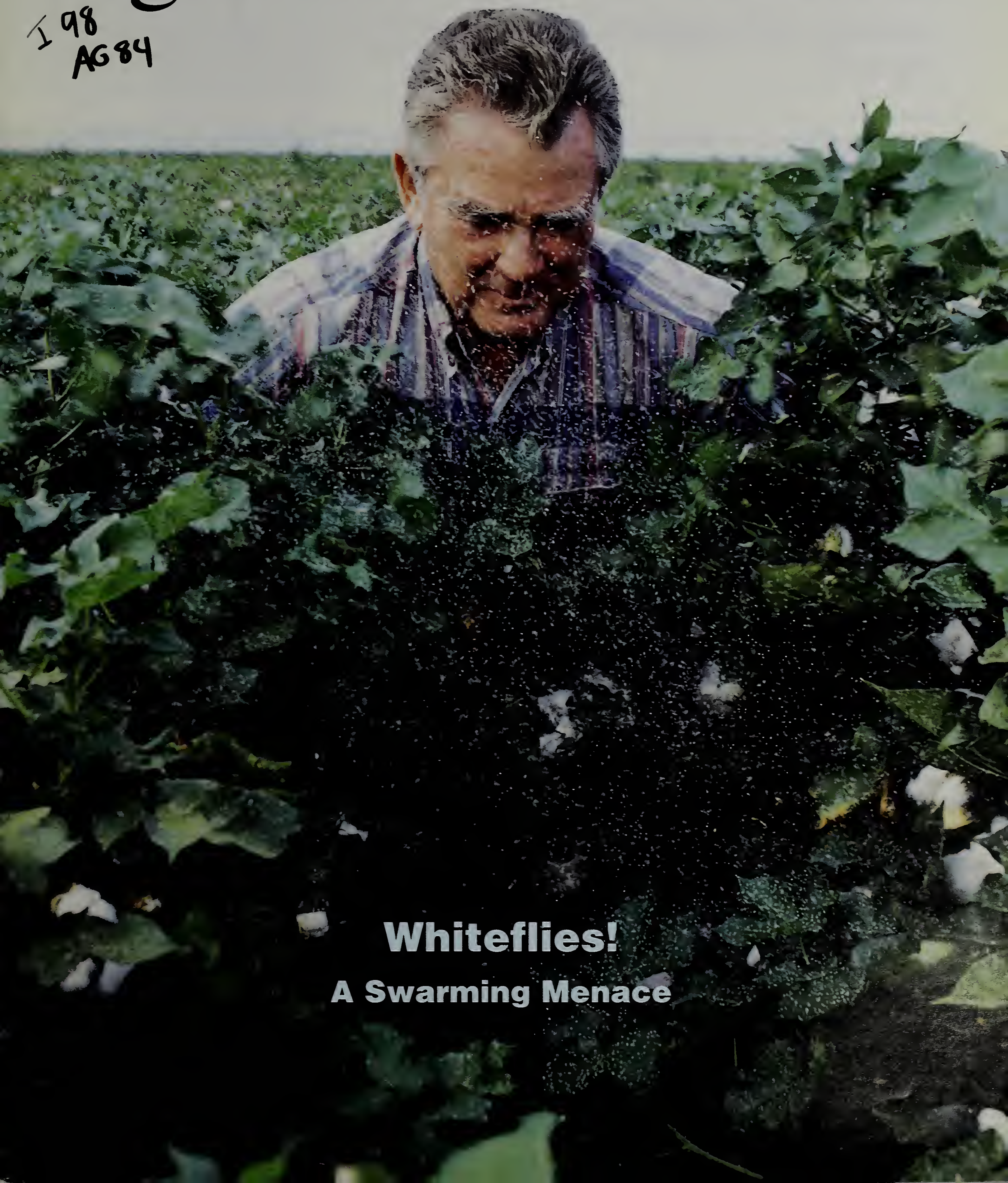

Whiteflies!

A Swarming Menace

Teaming Up To Swat the Whitefly

Last year, news media across the country reported that an apparently new strain of the sweetpotato whitefly, *Bemisia tabaci,* was playing havoc with agriculture. Pestilential clouds of millions of the diminutive insects swarmed through vegetable, cotton, and other fields in the Southwest.

Many researchers had feared something like this might happen. So they expanded their anti-whitefly efforts shortly after the insect was first found in 1986 on poinsettias in Florida. And they have found chinks in the whitefly's armor, according to this issue's cover story.

In 1987, scientists' alarm increased when two new crop diseases blamed on the whitefly—tomato irregular ripening and squash silverleaf—appeared in Florida. The next year, the state's tomato growers suffered major losses because of the ripening disorder. Both diseases have since been seen in Puerto Rico, the southwestern United States, and Hawaii.

In the fall of 1991, the pest struck alfalfa, cotton, lettuce, melons, and other crops in Arizona, California, Florida, and Texas. Local and state officials and university experts reported multimillion-dollar losses to crops and farm-area economies.

Scientists—like growers—were stunned by the level of damage in some fields. "I haven't seen anything like this pest in 32 years as an entomologist," James Coppedge remarked in late October 1991 on his way to a meeting in Atlanta on the problem.

Atlanta was in delirium over its baseball Braves, then battling the Minnesota Twins in the World Series. But Coppedge and Robert Faust, both with the Agricultural Research Service's National Program Staff, were interested in whiteflies, not long fly balls. They coordinate the agency's whitefly research.

In Atlanta, ARS assembled two dozen USDA and university scientists and state and industry representatives to work out the first steps toward a national anti-whitefly plan to be developed over the coming winter.

The Twins beat the Braves, and the whitefly kept throwing strikes at agriculture. In October 1991, shipments of cantaloupe and honeydew melons from California's Imperial Valley plummeted more than 90 percent from October 1990, according to the Imperial County agriculture commissioner.

Later, California employment officials reported that whitefly damage to fall and winter crops caused the loss of about 2,000 jobs in the Valley's agricultural sector. This summer, few growers planted melons for this fall's harvest.

In the Lower Rio Grande Valley of Texas last year, the whitefly caused revenue losses of $22.6 million in cotton and $29.1 million in vegetables, according to crop specialists at Texas A&M University's Agricultural Research and Extension Center in Weslaco. The specialists estimated that these losses contributed to a total impact of $168.5 million on the area's economy, including the loss of 4,300 jobs.

In February 1992, 150 scientists and other experts with USDA, 12 universities, affected states, and the agriculture industry developed the 5-year National Research and Action Plan for Development of Management and Control Methodology for the Sweetpotato Whitefly.

The flexible, coordinated plan was designed to avoid duplication of effort and make the best use of available funds and personnel. It now guides cooperative efforts in six broad areas:

- whitefly ecology, population dynamics, and dispersal
- fundamental research (behavior, biochemistry, biotypes, morphology, physiology, systematics, viral diseases, and virus/vector interactions)
- chemical and biorational controls (such as plant extracts) and application technology
- biological controls
- crop management systems and host plant resistance
- integrated techniques, approaches, and philosophies.

"The overall goal is to find which method or combination of methods best controls the whitefly in a given area," says Faust.

This year, heavy rains held down early summer populations of whiteflies in Texas, but heat waves in Arizona and California helped them reach damaging levels in cottonfields 3 to 4 weeks sooner than last year. By the first week in August, whiteflies had defoliated 25 to 40 percent of the cotton growing in the Imperial Valley and near Yuma, Arizona. Cotton yield and fiber quality will suffer.

And in September, ARS scientists confirmed they had found the pest in fields in California's San Joaquin Valley, one of the nation's most productive farming regions. They hope the valley's winters—cooler than in the Imperial Valley—prove too cold for the whitefly.

Where did this plague come from, anyway? Did it arise in this country, or stow away on imported plants or agricultural goods from any of the dozens of countries where *Bemisia* whiteflies already occur? No one knows for sure. Invasion would be no surprise, Faust says. While the United States has an excellent quarantine and inspection system, the chances for pest invasions rose during the 1980's with increased foreign trade in food, fiber, and plants.

The most important question, however, is not where it came from but when it will be brought under control. "Only time will tell," Faust says. "We began increasing our research in the late 1980's when we saw the first storm clouds in Florida, instead of waiting for the flood to hit the Southwest last year. Some of the fruits of those early efforts may already be turning the odds in our favor."

Jim De Quattro
ARS Information Staff

Agricultural Research

Cover: Rousing a flurry of whiteflies, plant pathologist James Duffus wades through a Blythe, California, cottonfield.
Photo by Ed McCain. (K4851-1)

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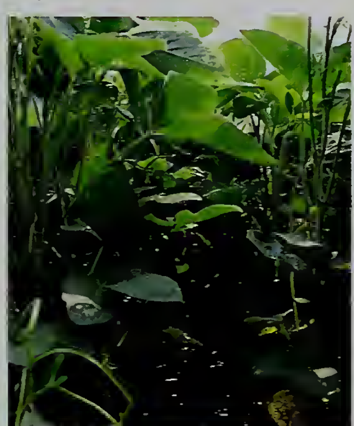

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Get the Whitefly Swatters—*Fast!*

They are not much larger than the head of a pin. Yet these flat, white bugs have so deeply wounded agriculture in the Southwest and Florida that the mere thought of them makes growers shudder.

The pests, currently considered a new strain of sweetpotato whitefly, were first found on Florida greenhouse poinsettias in 1986. Ever since, they've been munching their way—nearly year round—through crops in California, Texas, Florida, and Arizona. They suck the sap from more than 600 plants including fruits, vegetables, ornamentals, alfalfa, and cotton. In their wake last year, they left multimillion-dollar crop losses and other damage.

While producers worry and count up their losses, scientists try to get a handle on how to control the insects.

Around the country, researchers struggle to help. They're showing the textile industry how to wash off the sticky goo the insects deposit on cotton fiber. They're uncovering ways to alleviate plant viruses carried by whiteflies. And they're testing legions of environmentally friendly controls: insect parasites and predators, fungi, extracts of exotic plants—even dish detergent mixed with vegetable oil.

To get the job done, the Agricultural Research Service and other USDA agencies—Animal and Plant Health Inspection Service, Cooperative State Research Service, and Extension

Whiteflies suck the sap from more than 600 plants including fruits, vegetables, ornamentals, alfalfa, and cotton. In their wake last year, they left multimillion-dollar crop losses and other damage.

ED MCCAIN

Looking like the season's first snow, whiteflies settle on a cotton plant. (K4853-3) Inset: Adult sweetpotato whitefly. (Photo by Scott Bauer. K4600-6)

A Pest Is a Pest ... Or Is It?

Is the whitefly pest merely a new or previously unidentified strain (called biotype B) of *Bemisia tabaci*—a species that invaded the United States from Eurasia about 100 years ago? Or is it another species altogether?

The answer may be crucial. For example, while some beneficial wasps attack many species of *Bemisia,* others are extremely picky. Before scientists can recommend deploying a given wasp in a big way, they must determine whether it will aggressively pursue this particular whitefly.

Fortunately, scientists can distinguish the two insects. But the assignment of official taxonomic labels is still an unsettled matter. Traditionally, species are distinguished by differences in physical form and structure. And so far, "We haven't seen any differences that justify assigning the new pest to a different species," says ARS whitefly taxonomist Steve Nakahara.

This summer, however, scientists at the agency's Western Cotton Research Laboratory in Phoenix turned up provocative evidence to the contrary. Geneticists Nick Gawel and Alan C. Bartlett relied on a high-tech method called RAPD-PCR, short for "randomly amplified polymorphic DNA-polymerase chain reaction." In several hours' time, RAPD-PCR can multiply—more than a million times—specific sequences of the four chemical bases in the nucleic acids that make up genes. Bartlett and Gawel used PCR-amplified sequences to compare genetic material from whiteflies in biotypes A and B.

In each of 20 separate PCR comparisons, Gawel and Bartlett found striking genetic differences. "If the insects were the same species, all tests would have shown close similarities," says Bartlett.

But other genetic evidence supports the idea that the new pest,*B. tabaci,* is like the better-known but less destructive biotype A of sweetpotato whitefly. Certain genes—such as those that make ribosomal RNA (rRNA)—serve as a kind of evolutionary clock, explains entomologist Bruce Campbell of ARS in Albany, California. "By comparing sequences in the RNA's nucleotide building blocks, we can estimate how closely species are related."

Recently, Campbell compared more than 1,000 nucleotides and found that the two whitefly biotypes' rRNA's were 99.8 percent similar.

He and colleagues also found highly similar rRNA's in beneficial bacteria that whiteflies inherit from their mothers. "Both of these rRNA indicators," he says, "appear to be too similar for the insects to be different."

A classical test of whether two insects are the same species is if they can mate and, more important, produce fertile offspring of both sexes. Female whiteflies need not mate to produce males, but they must mate to produce females. In lab studies in which the two biotypes had opportunities to interbreed, they produced few female offspring. But there are several reasons why the insects of the same species might fail such tests.

It would be convenient if insects were born with labels, but *Bemisia* whiteflies have a history of thwarting taxonomists' efforts to pigeonhole them. One *Bemisia* trademark is unusually high variation in physical form and structure, host plant preference, behavior, and other factors. Not long before the new pest burst on the scene, in fact, taxonomists folded 18 previously "different" *Bemisia* species into the single species *B. tabaci.* And the debate over their correct placement will probably continue.

"The consensus of the scientific community, based on all the evidence, will eventually yield an answer," says James R. Coppedge, ARS national program leader for applied entomology. "Meanwhile, we have to attack this pest as best we can with what we now know."—**Jim De Quattro**

SCOTT BAUER

Biological aide Kyra Williams removes a beneficial insect, *Encarsia formosa,* from leaves to ship to scientists who are studying biological control of the whitefly. (K4730-12)

Service—have joined with a dozen universities, state agricultural experiment stations, and the cotton, vegetable, ornamental, and nursery crop industries.

The efforts are all part of a national research and action plan [See Forum on page 2]. "The overall goal is to find which method or combination of methods best controls the whitefly infestation in a given area," says Robert Faust, ARS National Program Leader for crop protection, who is also one of the two coordinators of ARS' anti-whitefly effort.

But scientists have been dogged by complications that make the task more difficult—starting with the pest's true identity.

The sweetpotato whitefly—*Bemisia tabaci*—has been in the United States since the 1890's. Scientists have been calling the newly emerged pest "biotype B" of this species. But tests suggest it may be a different *Bemisia* species. [See box, previous page.]

Whatever you call it, its numerous biological advantages make control difficult. For starters, it reproduces about every 3 weeks, quickly becomes resistant to synthetic insecticides, and has a wide-ranging appetite.

"We need a greater understanding of these and other biological and ecological factors. That should help us determine the best ways to control this whitefly by the many routes we're already exploring and by others we hope to turn up," says Faust.

A Sugary Problem Sours the Cotton Crop

"For the cotton industry, these whiteflies could be the worst thing since the boll weevil," says Thomas J. Henneberry, director of the ARS Western Cotton Research Laboratory in Phoenix.

As whiteflies in Arizona, California, and Texas devour the sap from cotton leaves, they excrete partially digested sap and leaf sugars onto cotton fibers and leaves.

This excretion, euphemistically called honeydew, is similar to the sticky coating you may discover on your car if you parked it under a tree full of leaf-sucking insects. Honeydew can reduce prices paid to cotton growers, since fiber contaminated with it gums up cotton gins and interrupts processing in the textile mill.

About a year ago, University of Arizona scientists discovered that whitefly honeydew contains a sugar called trehalulose. Until then, this sugar apparently had been found only in microorganisms.

Later, ARS scientists at the Phoenix cotton lab found that trehalulose makes up about 40 percent of the sugar in the whitefly's honeydew. And they found something else.

"We discovered a sugar in the honedew of the biotype B whitefly that has never been reported to occur elsewhere in nature," says Donald L. Hendrix, ARS plant physiologist in Phoenix. He named the new sugar "bemisiose."

He says 80 percent of the honeydew sugars in the biotype B whitefly are a type known as nonreducing or poorly reducing—a reference to their reaction to classical simple sugar tests. Common reducing sugars include glucose, fructose, and galactose.

"Those tests work well to measure cotton lint contamination by cotton aphid honeydew, which has a higher percentage of reducing types of sugars," he says. "But this whitefly's honeydew has a preponderance of nonreducing and poorly reducing sugars. Those same tests therefore sometimes fail to measure the contamination."

In lab experiments to clean honeydew contaminated cotton fiber, the scientists sprayed the fiber with Tempanil, a commercial product from India. "One spray lowered the sugar content to one-fifth that of untreated cotton," says Hendrix. "Such treatments may alleviate the problem at gins and textile mills."

Chemicals that may ease processing problems are also of interest to ARS scientists and engineers at the Southwestern Cotton Ginning Research Laboratory in Mesilla Park, New Mexico, and at the Cotton Quality Research Station in Clemson, South Carolina.

"I think we have available to us compounds that will improve processing," says chemist Henry H. Perkins, Jr., who works at Clemson. The scientists are examining commercially available mineral oils and surfactants to see if they will ease processing of cotton that's too sticky to pass smoothly through equipment at textile plants.

Perkins and ARS engineer Ed Hughs at Mesilla Park are experimenting with correct amounts to spray on contaminated cotton before it begins its

Cotton leaf crumple is just one of many viruses the pest transmits—viruses that cause more than 40 other crop diseases worldwide and account for yield losses of 20 to 100 percent.

pass through high-speed textile-processing machinery.

Spreading Bad News: Viruses

As if honeydew and feeding damage weren't enough to contend with, the whitefly carries a disease known as cotton leaf crumple. Many varieties of upland cotton are susceptible to extensive damage from this virus-caused disease.

Fortunately, researchers have developed germplasm for resistant cotton lines.

"We bred resistant plants by crossing one of our most important commercial varieties with Cedix, a highly resistant or immune cultivar from El Salvador," says F. Douglas Wilson, plant geneticist at the Phoenix lab.

Wilson, with Judith K. Brown of the University of Arizona, identified two pairs of genes responsible for cotton leaf crumple resistance. "This information will allow cotton breeders to transfer greater virus resistance into commercial varieties," says Wilson.

Unfortunately, cotton leaf crumple is just one of many viruses the pest transmits—viruses that cause more than 40 other crop diseases worldwide and account for yield losses of 20 to 100 percent.

On the other hand, recent research indicates that biotype B whiteflies spread at least some viruses less efficiently than other biotypes do. [See box this page.]

Raiding Nature's Cupboard for Cures

Feeding, honeydew, and viral damage may be lessened if scientists can find ways to control or eradicate the six-legged source.

The sweetpotato whitefly can thrive on a continuous series of host plants in the warm climates of the Southwest and Florida, where crops grow year round. So interrupting the crop cycle could become an important tool.

Researchers are also scouring the landscape and the scientific literature for the sweetpotato

JACK DYKINGA

Plant geneticist Doug Wilson compares a normal cotton leaf with one deformed by cotton leaf crumple, a viral disease carried by whiteflies. (K4816-3)

Toxic Spit?

Much to the surprise of growers and scientists, the new biotype B whitefly is a wimp at spreading plant viruses. Its type A cousin, which has been around for decades, does a far better job.

"Growers have already seen that their problems with type B whiteflies aren't due to viruses," says ARS plant pathologist James E. Duffus who is based in Salinas, California.

The question ... is: Why? The answer may be in the whitefly spit that spreads plant viruses.

Both types of whitefly, Duffus explains, use a strawlike stylet to puncture the veins of a plant leaf. Then the insect sucks out the sweet juices—and virus particles that may be present. As the pest moves to other plants, its virus-laden saliva can give the disease a new home.

But the saliva, Duffus points out, also contains a natural toxin that can kill the virus. And saliva of the biotype B whitefly may carry more of this toxin than biotype A. He believes this difference could explain why, for example, biotype B is about 100 times less effective in transmitting lettuce infectious yellows virus, which attacks lettuce and sugarbeets. His own tests have shown that biotype B is also a weaker vector of squash leaf curl, a viral disease of squash and melons.

Duffus is testing the toxic-spit theory in his lab at ARS' U.S. Agricultural Research Station.

"In the future," he says, "it might be possible to move the gene responsible for the anti-viral compound into plants like lettuce. That would give the plants new, natural protection against viruses."—**Marcia Wood**

Researchers are scouring the landscape for the sweetpotato whitefly's own natural insect enemies. So far, they've identified some 30 predators and 25 parasites.

whitefly's own natural insect enemies. So far, they've identified some 30 predators and 25 parasites.

In Arizona, ARS has given one native predator, the big-eyed bug, a dietary boost, making it feasible to rear and release it in massive numbers.

When a big-eyed bug attacks an adult sweetpotato whitefly, its mouth parts exude a sticky substance that glues the pest's wings to the plant. The whitefly can't take off, and the bug proceeds to eat it.

Next summer, USDA's Animal and Plant Health Inspection Service (APHIS) will be ready to use an ARS-designed, hamburger-based diet to rear and release several hundred thousand big-eyed bugs. Smaller releases may be made sooner.

ARS entomologist Allen C. Cohen designed the diet to replace a far costlier rearing method—growing plants to feed to insects that big-eyed bugs, in turn, like to eat.

Cohen, who is with the Western Cotton Research Laboratory in Phoenix, developed the diet after studying Agriculture Handbook No. 8, the bible for human nutritionists.

"I knew what the big-eyed bugs ate in nature—other insects. So I gathered some of these insects and analyzed them for their nutritional content. Then I used the handbook to see what readily available foods closely matched their natural diet," says Cohen. The main ingredients are hamburger, liver, and sugar solution.

Last January, for the bug's first field test, Robert T. Staten and Nick Colletto of APHIS used Cohen's recipe to rear big-eyed bugs from hatchlings to immature adults. In Phoenix, Staten directs APHIS' Methods Development Center for beneficial insects.

Having glued a hapless whitefly to a leaf, the big-eyed bug can devour its prey at its leisure. (K4813-20)

Once the bugs reached early adulthood, they were released along with whiteflies into cages in alfalfa fields in California's Imperial Valley. The big-eyed bugs devoured up to 40 percent of the whiteflies. Another successful test—in grapefruit trees—was run in February and March.

Named for its bulbous eyes, the big-eyed bug is a native of the United States and Mexico. Adult bugs are about half the size of Lincoln's head on a U.S. penny and are gun-metal gray.

A different predator, a tiny beetle, has an appetite that's somewhat like the whitefly's—insatiable. But while the whitefly feeds almost indiscriminately on plants, the picky *Delphastus pusillus* beetle savors only whiteflies—plenty of them—in all stages, from eggs to adults.

The shiny black *Delphastus* is a Florida native that's also found across the central and southern United States, through Central America and the Caribbean, and as far south as Peru. ARS scientists in Orlando, Florida, are studying and testing the beetle in cooperation with the University of Florida.

"It's hard to rear the beetle because of its demanding appetite," says Kim A. Hoelmer, an ARS entomologist at the U.S. Horticultural Research Laboratory in Orlando. "One beetle can devour several hundred whitefly eggs a day."

And during the beetle's 6- to 9-week lifetime, it can consume as many as 10,000 whitefly eggs or about 700 nymphs.

JACK DYKINGA

Entomologists Allen Cohen (left) and Robert Staten of APHIS check the well-being of big-eyed bugs, which have been reared on Cohen's hamburger-based diet. (K4815-2)

"To raise whiteflies as food for the beetle means growing and maintaining host plants and infesting them with the insect," says ARS Orlando entomologist William J. Schroeder. "That's time consuming and expensive."

Instead, researchers are first trying citrus weevil and Caribbean fruit fly eggs. "We're hoping one or both types of eggs will appeal to the beetle's discriminating palate," Schroeder says.

Just in case that doesn't pan out, he and Hoelmer are working on an artificial diet for the beetle. It has already been distributed to several companies for testing in commercial *Delphastus* rearing.

Recruiting Wasps for Whitefly Patrols

Strangely, the *Delphastus* beetle can detect a wasp-infested whitefly and avoid it, searching instead for a healthy specimen for dinner, says Hoelmer.

So, a whitefly snubbed by the beetle may have been attacked by any one of five parasitic wasps studied at Orlando.

The wasps include *Eretmocerus californicus* and four *Encarsia* species: *formosa, nigricephala, transvena,* and *tabacivora.* All are native to Florida, and none is harmful to humans, livestock, wildlife, domestic animals, or plants.

Another advantage of these wasps, Hoelmer says, is that they develop in as few as 12 to 14 days. Since the whitefly takes about 25 days to develop, the wasps have plenty of time to find, attack, and destroy their prey.

Other parasitic wasps that kill whiteflies are found abroad, and ARS researchers based in Montpellier, France, are exploring for them in several countries.

Promising anti-whitefly insects discovered on the trips are shipped to the United States and put into quarantine, usually at the agency's research quarantine facility at

Egypt's Whitefly Mummies

Two mummy hunters and their boatman glide across the Nile in a felucca, a small vessel bearing a single triangular sail.

The mummy hunters, entomologists with the Agricultural Research Service, reach their destination at an island not far from the Aswan High Dam.

The mummies they seek are dead sweetpotato whiteflies. But their real quarry is whatever killed these Nile whiteflies whose relatives have created a modern-day plague thousands of miles to the west.

While the boatman finds shade for a nap, Alan A. Kirk and Lawrence A. Lacey roam through a garden of botanical rarities. The scientists search the garden for the telltale red, pink, orange, and white blooms of lantana bushes. Soon they spot the flowers and, clinging to the small lantana leaves, hundreds of tiny, gray and black mummies encasing dead whitefly pupae.

Kirk and Lacey gather the lantana leaves, taking care not to dislodge the mummies. Many of the husks, or pupal cases, harbor living wasps that killed the whiteflies by feeding on them.

When Kirk and Lacey finish their collecting, they rouse the boatman.

By felucca, car, and jet, the wasps will travel to France, to the ARS European Biological Control Laboratory in Montpellier, 500 miles south of Paris.

If descendants of the wasps pass research tests there and in the United States, they could be reared by the thousands and set free to help solve this country's whitefly scourge.

The Montpellier laboratory serves as the staging area for Kirk, Lacey, and other ARS scientists searching for and studying potential biocontrol agents—insects, fungi, and other organisms—in Europe, Asia, North Africa, and the Middle East.

Over the past year, Lacey and Kirk traveled to seven countries to hunt for and collect the whitefly's natural enemies.

Scientists think the whitefly may be native to India and nearby countries, since many of its relatives abound there. Accordingly, Kirk and Lacey journeyed to Pakistan, Nepal, and India.

In Padappai, India, a village near Madras, the researchers discovered what Lacey calls "one of our most exciting finds," a fungus that invades and destroys adult whiteflies and immature ones, or nymphs.

"The infected whiteflies looked like woolly white patches on the leaves," says Kirk. Back in Montpellier, Lacey isolated a pure culture of the fungus, which is in the genus *Paecilomyces.*

The scientists sent samples of the fungus to researchers at the ARS Pathogen Quarantine Laboratory in Ithaca, New York, who will help identify the precise species.

Lacey and Kirk believe the fungus might thrive in regions of the United States that have a hot and humid climate similar to southern India's, such as Florida or the Texas gulf coast. It might also do well in a hot, dry area under irrigation.

A concept called "habitat and climate matching" guides the scientists' collection efforts. "It's important to find organisms that will do well in the various regions and climates found in the United States," says Lacey.

Scientists take detailed notes at each collecting site, such as the type of crop, nearby plants that might serve as alternative hosts for whiteflies, and the site's history of pesticide use. Geology, elevation, time of year, climate, and historical weather records are other crucial details.

Eretmocerus mundus wasps collected during a 1991 expedition have already been released to fight whiteflies in California and Texas.

"In our recent journeys, we've found *E. mundus* in many places from Spain to India, in many different habitats, and on many different crops," says Kirk. That increases the chances for a good habitat match with locales in the United States.—By **Julie Corliss,** ARS.

Besides insects, nature produces invisible enemies of the sweetpotato whitefly. One of them turns the ravenous pest into an inert puff ball.

SCOTT BAUER

Hibiscus plants growing in isolation harbor parasitic insects that will be shipped to whitefly researchers around the country. Biological aide Pat Lasby logs their progress. (K4731-2)

Stoneville, Mississippi. Before an insect is released from the facility, it must be identified according to genus and species.

"I think these new insects coming from Europe will be more difficult to identify than the wasps we have received so far," says Fannie Williams, quarantine officer at Stoneville.

A taxonomist at ARS' Systematic Entomology Laboratory in Beltsville, Maryland, is responsible for making the identifications.

Even if its identity is known, an imported biocontrol insect stays in quarantine for at least one generation before release. This gives scientists an opportunity to study it and ensure it will not pose a threat to crops or beneficial insects.

"We're searching for an extremely prolific wasp that will be a voracious parasite of the whitefly," says D.D. Hardee, director of ARS' Stoneville Insect Management Laboratory. "We're screening several species of wasps in hopes of finding one that fills the bill."

Imported *Encarsia formosa* wasps went through this screening process before their release to research facilities in California's Imperial Valley to aid the establishment of insect colonies in the region. The species is also indigenous to some areas in the United States.

The female *E. formosa* wasp stings immature whiteflies and lays its eggs on their undersides. When the eggs hatch, wasp larvae feed on the young whiteflies.

The stingless wasp *Eretmocerus mundus* takes a different tack, laying its eggs inside whitefly larvae and pupae. The adult wasp can also kill by directly feeding on its host.

While both of these wasps—and others—have cleared quarantine and show promise, Hardee says they aren't likely to be a quick solution. That's because finding "good" wasps isn't the same as knowing how best to use them.

"We suspect that the wasp's ability to parasitize or feed on young whiteflies may vary among different host crops," explains Hardee.

Entomologist Jo-Ann Bentz at the Beltsville Agricultural Research Center is currently working on a different piece of the wasp puzzle using the indigenous *Encarsia formosa.* How does it home in on its victim? "Once we know this mechanism we'll be better able to use wasps as biocontrols," she says.

Bentz has supplied a particularly aggressive strain of these wasps, which she found in Beltsville, to APHIS' mass-rearing facility in Mission, Texas. Earlier this year, APHIS reared and released 40,000 female *E. formosa* wasps in sunflower fields in Texas.

Fighting Back With Fungi

Besides insects, nature also produces microscopic enemies of the sweetpotato whitefly. One of them turns the ravenous pest into an inert puff ball.

Found in soil throughout the world, the fungus *Beauveria bassiana* was first identified in the 1870's. But a strain discovered by ARS entomologist James E. Wright killed up to 85 percent of the whiteflies in small test plots of cotton and vegetables.

The fungus kills immature whiteflies, or nymphs, by spreading through their bodies after contacting their outer covering, or exoskeleton.

"Eventually, the fungus covers the whole whitefly, so it looks just like a little white puff ball," says Wright, who works at the Subtropical Agricultural Research Laboratory, Weslaco, Texas.

Wright found the fungus on bodies of boll weevils, longtime pests of cotton. He was searching for a new way to knock down weevil populations without using pesticides.

Working with scientists at Fermone, a company in Phoenix, Wright developed a liquid formula—based on the fungus—to kill boll weevils. In tests with cotton, he says, the formula "completely controlled boll weevils—without any insecticides. Yields were

SCOTT BAUER

The fungus *Beauveria bassiana* makes short work of whiteflies on the underside of this leaf. (K4847-12)

as high on those plants as on other cotton sprayed with insecticides."

But boll weevils weren't the only losers. During field trials in 1990, Wright noted that the fungus kept whitefly numbers low. "The following year," he says, "we tried it again on cotton and for the first time on broccoli, bell pepper, cabbage, cantaloupe, celery, cucumber, tomato, and watermelon—with very good results."

The fungal formula is applied to plants in a fine mist, using conventional sprayers, special high-pressure sprayers, or airplanes.

Last summer, the U.S. Environmental Protection Agency granted Fermone an experimental use permit to test the fungus nationwide.

Most of the tests are against sweetpotato whiteflies: on cotton and vegetables in California, Texas, and Arizona; vegetables in Florida; and peanuts in Georgia and Texas. Other tests pit the fungus against boll weevils on cotton in Louisiana, Mississippi, and Texas.

SCOTT BAUER

Each fungus-treated cotton ball becomes a hazardous habitat for immature whiteflies. Research associate Barbara Mullen (center), technician Robert Brown (left) and entomologist James Wright score *Beauveria's* kill rate. (K4848-3)

In Orlando, Kim Hoelmer of ARS and University of Florida scientist Lance Osborne are testing a different natural fungus, *Paecilomyces fumosoroseus.* Isolated and patented by Osborne, the fungus destroys all stages of the whitefly. W.R. Grace Co. is licensed to develop and commercialize it as a biocontrol agent.

"Because of the patent rights, we can't say much about the research at this time, but suffice it to say this fungus carries a real wallop," says Osborne. "In addition to infecting all stages of the whitefly, the fungus tolerates pesticides and is easy to produce."

Hoelmer and William Schroeder have established experimental watermelon and tomato field plots to test the effectiveness of *P. fumosoroseus* and *B. bassiana.* Osborne is cooperating in the tests, which began in June.

Meanwhile, isolates of other fungal pathogens sleep—chilled in liquid nitrogen—in an ARS lab in Ithaca, New York.

"We have more than 200 samples of whiteflies that apparently died from fungal diseases," says insect pathologist Tad Poprawski who is with ARS' U.S. Plant, Soil, and Nutrition Research Laboratory.

The sleeping pathogens are mostly from Mexico's Baja California; the states of California, Florida, and Texas; Nepal; and Pakistan. They were collected by scientists based at Ithaca and other ARS locations including the lab in France, as well as colleagues at APHIS and universities.

Ithaca scientists have just begun the tedious work of isolating, identifying, reviving, multiplying, and testing the fungi. Poprawski says none of them are new species and some are the same species being tested by Wright and Osborne.

"There's no guarantee any of them will pay off, but anything that kills a whitefly is worth knowing more about," Poprawski says. "Finding just one good new pathogen isolate could make a big difference to growers."

Biosoaps To Wash Those Whiteflies Away

While natural enemies—insects and pathogens—may play a big role in controlling whiteflies, the reality is that most farmers rely on chemical insecticides as well as other conventional pesticides because they act more quickly than biological controls.

But many currently registered pesticides can harm natural enemies. To try to avoid this problem, scientists have turned to soaps, oils, and plant extracts.

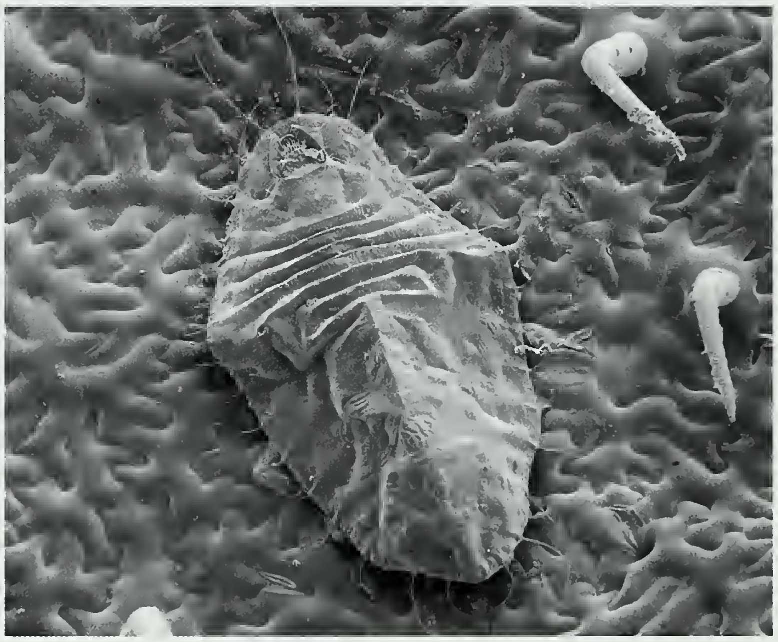
Researchers at the Beltsville center's Florist and Nursery Crops Laboratory hope to deal the whitefly a double blow from the stinging power of *E. formosa* wasps and a biosoap made from an Australian plant.

The plant, *Nicotiana gossei,* is a relative of tobacco, says Beltsville entomologist John W. Neal. "*Nicotiana* produces a detergentlike compound that kills whiteflies in their immature or nymphal stage," he explains. The extract easily mixes with water, and when sprayed as a biosoap in greenhouse tests, it gave nearly 100 percent control of whiteflies, along with aphids and mites.

Above, a healthy whitefly nymph has been placed on *Nicotiana gossesi*, an Australian relative of tobacco. Below, a desiccated whitefly bespeaks the power of the detergentlike substance *Nicotiana* produces. Magnification is about 200 times. (92bw1652, 92bw1653)

ERIC ERBE

ERIC ERBE



The experimental biosoap kills young whitefly nymphs by dissolving the waxy coating of their cuticle, or body covering. The researchers plan some tests in which they'll release wasps to clean up surviving whiteflies after the biosoap does its job.

The active compound in *Nicotiana* was isolated by George Buta of Beltsville's Horticultural Crops Quality Laboratory. Retired ARS agronomist George Pittarelli was first to note the compound's effect on the whitefly.

Of 66 known species of *Nicotiana,* only about half have been evaluated and several have yielded "very effective" extracts, Neal says.

Last summer, two of Neal's ARS colleagues in Georgia—agronomist Mike Stephenson in Tifton and chemist Ray Severson in Athens—grew *Nicotiana* plants and distilled extract from them for outdoor field tests at several sites around the country.

Another natural insecticide is found in the seed of a mahogany tree from India, known as neem. Available commercially, neem extract can control the whitefly in greenhouses.

More than a decade ago, ARS scientists helped identify one of the extract's active chemicals, azadirachtin.

"The extract disrupts hormonal changes in insect larvae, causing death during molting," says James Locke, a plant pathologist in the Florist and Nursery Crops lab.

The extract works against more than 80 other pests such as beetles, grasshoppers, aphids, weevils, fruit flies, gypsy moths, and mosquitoes. It doesn't harm beneficial insects, earthworms, birds, or humans.

The extract's complex molecular structure hinders target insects from becoming resistant—as some have with synthetic insecticides such as diazinon, malathion, and carbaryl.

At least three companies are marketing neem extract insecticides. Current-

Keeping the Garden Clean

For home garden use, here's the oil/detergent recipe devised by ARS researchers in Arizona for controlling whiteflies and other insect pests.

- Add one tablespoon of dishwashing detergent to one cup of vegetable oil—peanut, safflower, corn, soybean, or sunflower.
- When ready to use, shake this solution well and mix 1 to 2 teaspoons of it into 1 cup of water.
- Spray the mixture directly on insects, using a pump sprayer like the one that comes with plastic bottles of window cleaner.
- Check plants for insects every 7 to 10 days or so, and spray again as needed. The researchers sprayed the mixture to control pests on carrots, celery, cucumbers, eggplant, lettuce, peppers, Swiss chard, and watermelon.

NOTE:
The oil may burn tender leaves of squash, cauliflower, and red cabbage. Fresh garden produce should be washed well before use to remove any residual spray or other unwanted matter.—**Dennis Senft**

ly, they're registered for use only on ornamentals and other nonfood plants.

Grace Sierra Horticultural Products, Milpitas, California, sells to commercial growers an azadirachtin-based product, Margosan-O. For home gardeners, Ringer Corp. of Minneapolis, Minnesota, markets a similar product, BioNeem. AgriDyne Technologies of Salt Lake City, Utah, recently registered Azatin.

Locke and scientists at W.R. Grace Co. in Columbia, Maryland, are patenting other components from neem seed. Neem seed oil apparently repels whiteflies and may also protect plants from fungi that cause plant diseases such as rusts and mildew.

While extracts from exotic plants may thwart whiteflies in the future, other remedies may be right in your kitchen.

ARS researchers in Arizona found that a mix of common liquid dishwashing detergent and cooking oil kills sweetpotato whiteflies, as well as several common home garden pests. [See box, previous page.]

The detergent and oil act as pesticides, and the detergent makes the oil disperse into minuscule, easily spread droplets.

"It's simple to mix and as effective as commercial insecticides that may cost three times as much. And it's clean environmentally," says George D. Butler of the ARS Western Cotton Research Laboratory.

"We used commercial spray equipment to apply the mixture on cottonfields," adds lab director Thomas Henneberry. "Results were encouraging—we killed 50 percent of the adult whiteflies.

"But the pests seek protection from sun and wind by hiding under plant leaves, so we must be careful to spray all leaf and stem surfaces with a light coat."

Unfortunately, Henneberry notes, most commercial cottonfields are sprayed by airplanes, with an insecticidal mist that covers only the tops of the leaves.

JACK DYKINGA

At test plots in Maricopa, Arizona, technician Barbara Hefner and biological aide Bryan Merrill spray a cottonfield with a fine mist of vegetable oil and dishwashing detergent. (K4817-4)

Entomologist David H. Akey is working to modify ground sprayers. For example, he is installing special pipes and upward-tilting nozzles that will direct the spray to the undersides of leaves. "Then we can try using oil/ detergent mixtures on a commercial scale," says Henneberry.

"Modified sprayers could also apply other kinds of sprays—conventional insecticides as well as promising new ones such as fungi and plant extracts."

At three research farms in Arizona and California, scientists from the Phoenix center are testing all these types of control agents—on a variety of crops and with four types of modified sprayers.

"This kind of comprehensive testing is possible only because of the extensive cooperation and coordination between researchers at ARS labs and our university colleagues," says Henneberry. "That cooperation is the glue that holds together all the components of the national whitefly plan we worked out last winter."—**Hank Becker, Julie Corliss, Jim De Quattro, Marcie Gerrietts, Dennis Senft, Doris Stanley, and Marcia Wood** contributed to this article.

For more information about ARS whitefly research, contact: James R. Coppedge, USDA-ARS-National Program Leader for Applied Entomology, Room 212, Bldg. 005, 10300 Baltimore Ave., Beltsville, MD 10300, phone (301) 504-5541, fax number (301) 504-6122 or Robert M. Faust, USDA-ARS-National Program Leader for Fundamental & Molecular Entomology, Room 338, Bldg. 005, 10300 Baltimore Ave., Beltsville, MD 20705, phone (301) 504- 6122, fax number (301) 504-5467. ◆

Less Stressed Spuds Are Best

A potato grown for processing stands many chances of getting bumped and bruised between the time it's harvested until it's made into fries or chips.

But in a vat of hot cooking oil, even the slightest internal bruise from the spud's past may be exposed. The heat turns damaged potato tissue—which has converted much of its starch into sugars—to an unattractive dark brown.

"Most people prefer light-colored chips and fries made from undamaged potatoes," says Paul H. Orr, director of the Red River Valley Potato Research Laboratory, East Grand Forks, Minnesota. "So our biochemical and agricultural engineering studies are aimed at both improving potato product quality and reducing costly handling and storage problems."

The research is financed, in part, by the Red River Valley Potato Growers Association.

Breeding Splendid Spuds

Working with researchers at North Dakota State University and the University of Minnesota, ARS scientists have developed standardized tests to rate processing qualities of potatoes that are showing promise in state and federal vegetable breeding programs.

For example, University of Minnesota biochemist Joe R. Sowokinos, stationed at the ARS potato research

BRUCE FRITZ

Agricultural engineer Paul Orr records the time it takes an artificial potato to pass through each section of a bulk potato loader. (K4830-2)

lab, has shown that cultivars considered ideal for chipping must be low in sucrose content at harvest time and convert minimal amounts of starch to reducing sugars (glucose and fructose) during storage.

Orr coordinates annual testing of processed products made from potatoes sent to the laboratory from several state breeding programs. These products must pass tests for flavor, color, and texture by a trained sensory/taste panel under the direction of North Dakota State University food scientist Edna T. Holm.

One new cultivar judged especially good for fries— if not bruised—is Ranger Russet, developed by ARS scientists Joseph J. Pavek and Dennis L. Corsini of Aberdeen, Idaho, and by university, Cooperative Extension, and industry researchers in Washington, Oregon, Idaho, and Colorado. [See *Agricultural Research,* April 1991, pp. 4-9.]

Into some experimental potatoes, biochemist William R. Belknap of the ARS Western Regional Research Center, Albany, California, has introduced a gene from a wax moth that might help prevent ugly black spots from forming in bruised tubers. Corsini, Pavek, and researchers in North Dakota, Minnesota, and Maine are field-testing these potatoes' production qualities and bruise resistance.

Better Bin Management

In East Grand Forks, scientists are trying to find out when and how bruising occurs so as to better prevent such damage. To measure the impact of handling jolts, Orr's research team puts an artificial potato—a battery- powered instrumented sphere just 3-1/2 inches in diameter—amid potato samples.

Developed by ARS and scientists at Michigan State University, East Lansing, the beeswax sphere encases impact-detecting devices called accelerometers, along with computer circuitry that records the data. [See "'Apple' Computer Records Impacts," *Agricultural Research,* August 1991, p. 17.]

But bruises are not the only injuries that concern these researchers. Potatoes with cuts and scrapes from handling equipment—especially at harvest time— are highly vulnerable to moisture loss and serious storage diseases.

BRUCE FRITZ

Tissue-cultured minipotatoes are helping scientists develop tough-skinned spuds that store well. (K4825-l)

These all end up costing the industry dearly— perhaps a quarter-billion dollars by the time 27.5 billion pounds of potatoes have come out of storage, some 10 months after harvest. Obviously, says Orr, most potatoes grown for processing have to be stored until they can be fried, flaked, or granulated.

Keeping damaged spuds from rotting and spoiling other healthy potatoes in the bin is a challenge. Growers carefully try to help the still living and breathing tubers heal during the first week or two of storage. Throughout this critical time, warmth and moisture regulated by minimal ventilation enhance suberization—the process that forms potato skins and scar tissue over wounds.

Considering the size of a typical 20-foot-high storage bin, any mistakes in bin management could be hazardous to a grower's financial health. Larger than the volume of the average American home, each bin holds about 1,300,000 pounds of potatoes worth perhaps $65,000.

Research at East Grand Forks may help storage managers make the best decisions on bin and equipment use during hectic days of harvest and suberization. ARS agricultural engineer Lewis Schaper led the development of SUBERMAX, a computerized expert system, to assist in making decisions for managing potatoes that are either healthy or stressed.

Schaper says SUBERMAX may be revised as often as every 2 years, as new information is gleaned from research and from commercial practices. Soon the system may include data from automated sampling of various gases, as well as temperature and humidity measurements, taken from various sites throughout the bin.

Sudden changes in these gases might signal developing disease problems. Rather than risk large- scale damage, managers may then decide to sell the potatoes for immediate processing rather than hold them for anticipated higher prices.

About Sprouting...

Other unfavorable changes that affect processing qualities of potatoes in storage result from sprouting. Sprouting tubers quickly lose weight and soften. Much of their starch turns into reducing sugars that, when cooked, react with amino acids—the Maillard

Enhancing the Wound-Healing Process

Apart from handling, storage management, and marketing decisions, one way to minimize spoilage and reduce unsightly blemishes is to increase the resistance of potatoes to harvest damage and assure that potatoes wounded during harvest heal rapidly.

Toward that end, ARS biochemist Edward C. Lulai of the Red River Valley Potato Research Laboratory has refined techniques to measure the effect of potato storage environment and treatments on wound-healing rates.

To study the biochemistry of suberin, a wound-healing substance found in injured potato skins, Lulai and coworkers developed a technique to make its components fluoresce for microscopic examination. Such detailed study may enable researchers to relate various suberin components to the activation of specific potato genes.

And Lulai says damages may also be significantly reduced by breeding potatoes to resist skinning injury.

Using an experimental device developed by agricultural engineer James L. Halderson of the University of Idaho, Moscow, Lulai is testing the skin toughness of various genetic crosses as they mature in the field.

He and his colleagues hope to physiologically improve and identify breeding selections that will not only resist skinning but also have the biological mechanisms to resist disease if they are damaged.—**Ben Hardin**

reaction— making undesirably brown-colored chips and fries.

ARS plant physiologist Jeffrey C. Suttle, Fargo, North Dakota, is conducting research on potato sprouting at the cellular and subcellular level. Such studies may help breeders develop potato varieties that will sprout well at planting time but not in storage environments.

For more than three decades, storage managers have had to rely on one synthetic chemical to inhibit sprouting of stored potatoes. While a crop breeding approach is being pursued as an alternative, another natural inhibitor may fill in.

ARS plant physiologist Steven F. Vaughn and his colleagues at the National Center for Agricultural Utilization Research, Peoria, Illinois, have been issued two patents on the use of sprout inhibitors derived from volatiles, such as some major flavor components found in almonds, cinnamon, cumin, and thyme.

At East Grand Forks, scientists are researching these and other compounds to test sprouting inhibition under long-term, controlled storage conditions.

In still other research, ARS molecular biologist Yannis Gounaris and Sowokinos are studying biochemistry as related to cold- resistance in potatoes. Some cultivars—in response to cold temperatures in storage— readily develop the unwanted sugars that interfere with processing.

BRUCE FRITZ

Agricultural engineer Lewis Schaper doesn't need to see the 650 tons of potatoes behind this wall to monitor their condition. Uneven airflow in the storage bin allowing warm areas could induce sprouting or contribute to diseases. (K4827-1)

Some wild potatoes have genes that impart resistance to cold-induced sweetening. But transferring these genes to commercially acceptable cultivars may require the use of biotechnological techniques, rather than conventional plant breeding.

Gounaris has found that potatoes' sucrose content or cold-resistance is related to the density of mitochondria—energy-processing bodies within cells. In the mitochondria of potatoes sensitive to cold, he has found greater amounts of a certain protein that may help explain cold sensitivity. These discoveries may be stepping stones to identifying a cold-resistance gene.—By **Ben Hardin,** ARS.

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Evading the Shade

Can the spectral quality of shaded sunlight affect the quality of your food?

Maybe so, if you're fond of foods cooked in vegetable oil.

Recent findings by Agricultural Research Service scientists suggest that oleic acid levels in soybean seeds—the world's major source of vegetable oil—are related to the blue and far-red portions of sunlight falling on seed pods.

Oleic acid is a monounsaturated fatty acid that may help people ward off heart disease. Some studies have indicated that oleic acid lowers serum cholesterol. Less prone to rancidity, it has better storage and cooking properties.

Blue wavelengths increase the percentage of oleic acid in comparison to other fatty acids in the seeds, according to Steven J. Britz, head of the ARS Climate Stress Laboratory in Beltsville, Maryland. Wavelengths in the far-red part of the spectrum decrease the percentage.

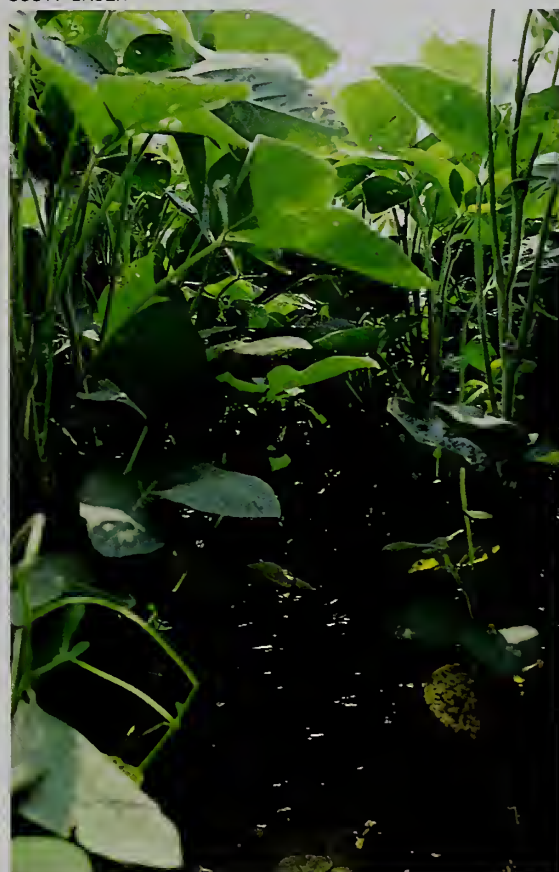
Direct, unshaded sunlight contains all the colors of the rainbow plus invisible ultraviolet and infrared bands. But dense leaf canopies block out much of the blue, Britz explains, while far-red (not quite infrared) wavelengths pass through.

"And that fact goes hand in hand with our observation that seeds from shaded pods tend to have less oleic acid," he says.

Britz and James F. Cavins, head of the ARS Analytical Chemistry Support Unit in Peoria, Illinois, compared the effects of broad-spectrum light (containing all visible wavelengths) and blue-deficient light on soybean plants. Their study, which included soybean plants grown in greenhouses and controlled environment chambers, was part of an ongoing research program to examine crop responses to various lighting conditions.

The scientists found that soybean seeds contained 50 percent more oleic acid when pods received direct, broad-spectrum light. Removing the blue or adding far-red reduced oleic acid to levels associated with shaded pods. Seed yield, protein, and total oil were the same with either kind of light.

SCOTT BAUER



Shading from soybean leaves decreases the percentage of oleic acid in the seeds in relation to other fatty acids. (K4810-20)

"Evidently," says Britz, "the metabolism of oleic acid into more highly unsaturated fatty acids is retarded by photoreceptors that respond mostly to wavelengths in the blue region of the spectrum."

Now comes the big question: How can soybean growers take advantage of this information?

Soybeans are usually grown close together to maximize yield, Britz points out. So mutual shading—and the loss of blue light as far as the pods are concerned—is probably unavoidable for economic reasons.

But there's more than one way to solve the problem. "If we can't get the seed pods out of the shade," Britz says, "then maybe we can help them evade the effects of shade."

Britz proposes the selection and breeding of soybean plants with more efficient blue light photoreceptors as one possibility. The seeds could then make better use of whatever blue light they do receive. Another possibility might be development of pods with different light-absorption characteristics.

"In other words," says Britz, "we need to genetically trick soybean plants into responding as if there were no shade—as if their pods were getting all the blue that direct sunlight normally provides."

That's easier said than done, Britz acknowledges. Breeding specific kinds of photosensitivity into plants could be a trial-and-error process taking years, and there's no guarantee of success.

But the blue light connection could make a big difference, according to plant physiologist Richard F. Wilson, head of the ARS Soybean and Nitrogen Fixation Research Unit in Raleigh, North Carolina. There are more than 14,000 soybean varieties in the ARS soybean germplasm bank, he points out, so faster techniques for genetic screening are always needed. And if more oleic acid is the goal, he adds, then checking for blue light sensitivity in soybean germplasm might indeed be the best way to achieve it.—By **Stephen Carl Miller,** formerly with ARS.

Steven J. Britz is at the USDA-ARS Climate Stress Laboratory, Bldg 046-A, 10300 Baltimore Ave., Beltsville, MD 20705-2350. Phone (301) 504-5607, fax number (301) 504-6626. ◆

The National Parasite Collection

Scientists from all over the world are drawn to this relatively small, environmentally controlled room.

The room contains specially constructed movable shelves storing rows of bottles and boxes of microscope slides containing preserved parasites.

Welcome to the U.S. National Parasite Collection— one of the world's largest collections of livestock and human parasites!

Most of the specimens are roundworms such as hookworms, or flatworms such as tapeworms, but protozoans and arthropods such as ticks and mites are also included.

"This ARS collection is 100 years old this year and is actually a series of collections that are available for study by scientists worldwide who can obtain specimens or samples from the collection on loan," says J. Ralph Lichtenfels, the present curator.

Scientists are not only welcomed, they are encouraged to visit the collection, which is located at the Beltsville Agricultural Research Center, Beltsville, Maryland. It has been at Beltsville since moving from Washington, D.C., in 1936.

Constantly growing, the collection adds about 1,000 new samples each year to the almost 90,000 in the specimen base. Associated with it is a library of 4,000 volumes and over 52,000 reprints from scientific journals dealing with parasites.

ARS maintains the collection—as it does several other national biological collections—because it is an essential working tool for ARS animal scientists. It operates as a national center for research on the identification and classification of parasites of food animals.

Why collect parasites? Because almost all of the biological sciences started out by naming and describing organisms. Systematics, or taxonomy, is the science of classification and study of organisms with regard to their natural relationships. Such study makes information about diverse organisms more usable by organizing it into an accessible form.

"We use the binomial system of nomenclature that was worked out 200 years ago. The system assigns an organism two Latin names, for genus and species, that are unique to it. This is the key to organizing all known information about parasites, or any other organism," says Lichtenfels.

SCOTT BAUER

Zoologist J. Ralph Lichtenfels retrieves a preserved large nematode parasite of swine for loan to another scientist. (K4733-1)

The collection's conservators also conduct research important to USDA regulatory agencies such as the Food Safety Inspection Service and the Animal and Plant Health Inspection Service. And they provide identification manuals and diagnostic aids that assist parasitologists, pathologists, and veterinarians in identifying parasites of medical and veterinary importance.

"Scientists have to first find out what they are working with before they can understand the problems parasites cause," says Lichtenfels. "Each species is a unique gene pool. There is nothing more important than knowing which pool of genes, or species, you are dealing with.

"And physicians and veterinarians need to know what they are dealing with to prescribe proper treatment. A good parasite collection is essential in the search for cures and controls for parasites of humans and animals," adds Lichtenfels.

Once parasitologists know what species they are studying, they can work out systems for controlling the parasites. For example, when scientists found that the life cycle of the hookworm included a stage that could penetrate the soles of bare feet, they advised wearing shoes to break the cycle of infection. "The ARS parasite collection helped make this possible," says Lichtenfels.

"Currently there are 70 important parasite collections around the world. But only two—in London and Moscow—are of comparable content, and only the London collection provides services comparable to those offered by the U.S. National Parasite Collection. Scientists in many countries use our collection because they do not have comparable facilities or services in their own countries," says Lichtenfels.

"We maintain a large number of types, or original specimens, that scientists discover. The types are given collection numbers that are published in research papers. Other researchers routinely borrow types to compare with parasites they encounter in their own studies," he adds.

"A great deal of the goodwill that we have established with the scientific community is because we maintain the specimens and make them available to the contributor or their colleagues on a timely basis," says Patricia A. Pilitt, co-curator of the collection and a second-generation curator. Pat's father, Allen McIntosh, was with the collection for over 30 years until his retirement in 1963.

SCOTT BAUER

Zoologist Patricia Pilitt examines parasite specimens that are on display and available for loan from the U.S. National Parasite Collection in Beltsville, Maryland. (K4734-4)

This dependability, along with 100 years of unbroken service, encourages scientists and organizations to donate other collections to the U.S. National Parasite Collection.

Many scientific journals require scientists who are making parasite surveys or ecological studies involving parasites to deposit voucher specimens in a bona fide collection. This is done so that other investigators can verify or even challenge the validity of the work. It also becomes a source of reference parasites for later scientists. The collection provides this service to the scientific community.

"We encourage parasitologists in all areas of research to make voucher specimen deposits. This helps attract new donors of parasite collections while keeping the ARS collection current with new parasite research," says Pilitt.

Adds Lichtenfels, "Parasitologists will always need this type of collection, but new technologies dictate that future parasite collections will change.

"One of the possible changes might be the addition of tissue banks. Samples of parasite tissue would be frozen or otherwise specially preserved to ensure the integrity of the DNA. The genes or DNA in the tissue would be an extremely accurate method for matching and identifying parasites via DNA fingerprinting," says Lichtenfels.

Scientists in the Biosystematic Parasitology Laboratory have already developed DNA probes to identify species of the nematode that causes trichinosis and several species of stomach worms and tapeworms of cattle and sheep.

The parasite collection of the future might also house a frozen-germplasm bank where parasites are stored in liquid nitrogen and later revived for research purposes.

Another feature for the future collection would be a centralized computer bank, preferably housed in the stable environment of a museum and containing computerized data on both private and publicly owned collections. Besides telling researchers where certain parasites are located, the computer could keep tabs on the well-being of the collections. For example, if a collection were in danger of losing funding, alternative sources might be arranged.

These and other changes "will prepare the collection to serve scientists for another hundred years," says Lichtenfels. By **Vince Mazzola,** ARS.

J. Ralph Lichtenfels and Patricia A. Pilitt are at the USDA-ARS Biosystematics Parasitology Laboratory, Bldg. 1180, BARC-East, Beltsville, MD 20705. Phone (301) 504-8444, fax number (301) 504-8979. ◆

Reading Snow Waves

When temperatures begin to fall and the skies turn gray foretelling the coming winter, plant physiologist C. Robert Olien takes to the air to track the growth of his fall-planted barley.

Olien's interest in aerial observation is helping him identify barley plants that show the best winter-hardiness, or ability to withstand the bitter cold of the northern United States. The information will be useful to plant breeders who want to build superior cold-hardiness into crops.

Once a week during the winter, Olien, who is in the ARS Sugarbeet, Bean, and Cereal Research Unit at East Lansing, Michigan, takes aerial photographs of the wavelike snow and ice patterns that cover his test plots. He uses a 35mm camera with a 50mm lens at altitudes from 500 to 1,000 feet.

"At first I tried charting everything by hand while standing on top of my car, but that just wasn't high enough," says Olien.

A colleague suggested erecting a pole that Olien could climb to get a better view of the snow-covered fields. But in the end, he decided that the best vantage point would be from an airplane: the best record, a photograph.

Daily high and low temperatures limit geographic distribution and productivity of plants. These limits, in turn, define the choices of crops that producers in the northern United States can grow.

Barley and other cereal crops that are planted in the fall, emerge and grow. Their ability to survive the winter varies depending on their ability to adapt to changes in the environment.

Plants' winter hardiness is influenced by the presence of freeze inhibitors, known as arabinoxylan mucilages, that interfere with the formation of ice crystals.

To maintain winter hardiness, a plant needs energy from photosynthesis. But in cold weather, buried under snow, the energy must come from stored sources. Sucrose, glucose, and fructose, along with the oligosaccharide fructan, are the primary energy reserves for cereal grains, he explains.

As winter progresses, several stress sequences occur. Each stress requires different biochemical activity to protect the plant and enable it to survive. The plants also need a snow cover to insulate against severe cold temperatures.

Recovery and regrowth of the plants in the spring depend on survival of the

crown meristem, the growing point of the plant just above the soil surface.

Olien found that ever-changing patterns of the snow and ice cover play a role in the variation of winter injury of a cultivar. The wavelike snow and ice patterns are partly due to topography of the field and drifting as the snow falls. "But in a relatively uniform field, wind and sun are the major factors," he says.

These patterns affect not only the condition of the plants beneath, but also the form and intensity of the stress that may lead to injury. Erosion of the snow and ice tends to induce changes in the chemical makeup and physical condition of the plant. But if the changes do not occur, the plant's susceptibility to injury increases as conditions become even more severe.

"Winter killing in Michigan is most likely to occur during low-temperature stress after a midwinter thaw, when crown tissues have a high moisture content," says Olien. Freeze injury typically occurs in a sequence of several thaw-freeze cycles. Other major forms of freeze injury are caused by adhesion and—under the most severe conditions—by freeze dehydration.

Olien superimposes several negatives of photos taken as winter progresses, to view the total effect of the variable environmental conditions.

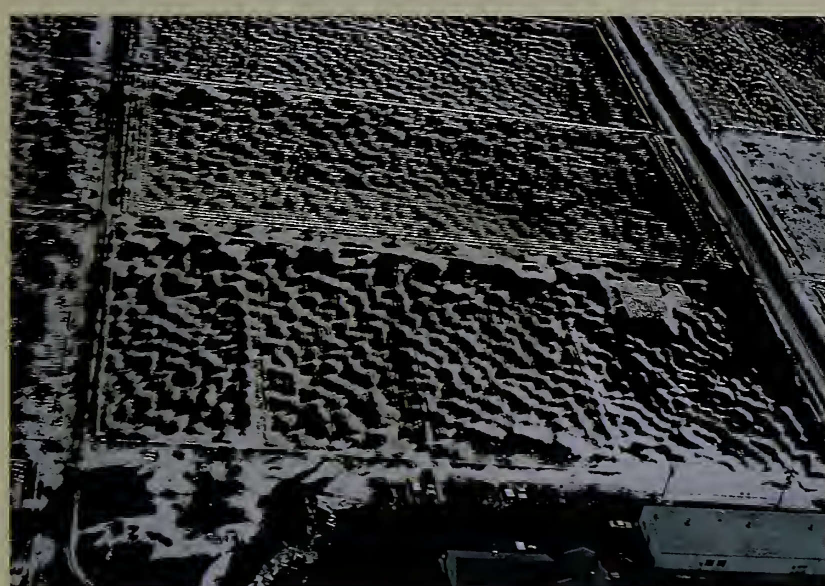
He also compares plants from the field to those grown under controlled freeze conditions in a laboratory growth chamber. And he examines tissue samples from both the field-and lab-grown plants.

Plants that prove to be the hardiest are tagged for use in breeding programs to improve the winter-hardiness of cereal crops.

"Ideally, we want to combine the best genes with the best management tools to get a quality product and high yield," says Olien.—By **Marcie Gerrietts,** ARS.

C. Robert Olien is in the USDA-ARS Sugarbeet, Bean, and Cereal Research Unit, Department of Crop and Soil Science, Michigan State University, East Lansing, MI 48824-1325. Phone (517) 355-2233, fax number (517) 353- 5174. ◆

Aerial photography by Robert Olien documents the accumulation and disappearance of snow on a Michigan barley field from November through February (top to bottom, pages 20-21). Wave-like patterns as the snow recedes affect the condition of fall-planted crops that are living out the winter. Plants without a protective snow blanket may suffer damaging freeze-and-thaw cycles.



Sweetpotatoes Ward Off Weeds

There's an old saying that if you have a problem with yellow nutsedge, you can always grow sweetpotatoes.

Now there's a scientific basis for that bit of folklore. Sweetpotato roots contain a compound that inhibits the growth of yellow nutsedge and certain other weeds—and may help explain why some weeds can't compete against sweetpotatoes.

Yellow nutsedge growth was reduced by 90 percent in 2 years of field studies where sweetpotatoes and the weed were planted together, says Howard F. Harrison, Jr., an Agricultural Research Service agronomist in Charleston, South Carolina. Yellow nutsedge is a perennial that causes problems primarily in vegetable crops, including snapbeans, onions, sweet corn, and tomatoes.

Harrison and ARS plant physiologist Joseph K. Peterson, also based at the U.S. Vegetable Laboratory in Charleston, are now working with ARS scientists in Beltsville, Maryland, to identify the compound responsible for sweetpotato's allelopathy—its natural ability to ward off competing plants.

That natural defense mechanism was also evident in greenhouse studies designed to eliminate competition by the sweetpotato for light, soil nutrients, and water. After 12 weeks, the presence of sweetpotatoes caused a 50-percent reduction in yellow nutsedge growth.

In additional lab studies, as little as 10 parts per million of a sweetpotato root extract inhibited the growth of yellow nutsedge roots. "It is much more potent than other suspected allelopathic compounds that have been studied," says Harrison, adding that the extract also inhibited velvetleaf and pigweed seed germination.

Sweetpotatoes, the sixth most important vegetable crop worldwide, are an excellent source of beta carotene, which the body converts to vitamin A. In 1991, U.S. sweetpotato production was about 1.1 billion pounds.

Other vegetables may also contain allelopathic compounds. Harrison and Peterson have now started searching for allelopathic compounds in squash, cucumbers, and other cucurbits.—By **Sean Adams,** ARS.

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Grazing Moldy Fescue

Lighter calves can be the result when a grass called fescue tangles with the calf's "family tree."

A 3-year study has shown calves may weigh less at weaning if their mothers grazed fescue infected with a fungus—a common situation throughout the upper Midsouth. But the severity of the drop in weaning weights may hinge on the breed of the mother.

In the study, 160 purebred Angus or Brahman cows grazed pastures of either bermudagrass or fungal-infected fescue.

The cows were bred to Brahman or Angus bulls, and all the resultant crossbred calves shared the same genetic makeup: half Brahman, half Angus. But in some instances, the Angus blood came from the calf's mother, whereas other calves inherited their Angus blood from the father.

"On bermudagrass, the crossbred calves from Angus mothers weighed about 507 pounds at 205 days of age, compared with an average of 481 pounds for crossbred calves out of Brahman mothers," says Michael A. Brown, research leader at the ARS South Central Family Farm Research Center at Booneville, Arkansas, site of the study.

"On the infected fescue, the gap between the two was not as large—456 pounds for the calves from Angus mothers compared with 445 pounds for those from Brahmans. There was a more dramatic decline in weaning weight for calves from Angus mothers."

The culprit behind weaning weight losses is the fungal infection in the fescue. Infected forage can contain a toxin from the fungus that interferes with the animal's body temperature regulation and circulatory system.

Although this is hard on any breed, Brahmans are less affected than other breeds when it comes to grazing infected fescue. They are able to better dissipate body heat, so even though the toxin has reduced the outside blood supply to skin, ears, and tail, the animals can still cool themselves, says Brown.

In addition to monitoring the growth of the calves, the researchers regularly measured milk production of the mother cows.

Angus milk production dropped more than 3-1/2 pounds a day on infected fescue versus bermudagrass, whereas the fescue reduced Brahman milk production only about a pound a day.

"We're trying to show the effect of fescue as part of a grazing system," says Brown. "As we learn how to manage infected fescue, this study shows that breed of the mother is another component that cattle producers can work with in planning their herd management."—By **Sandy Miller Hays**, ARS

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Out-of-This-World Corn on the Cob?

Planners wrestling with menus for future space station astronauts could consider corn on the cob.

"Hypothetically, corn could be grown in space," says J. George Buta, an ARS chemist who specializes in growth hormones.

Buta helped perform a chemical analysis on corn plants that had circled the Earth for 5 days in 1989 on the Atlantis shuttle.

He found that growth hormones in the space-grown plants were no different

from those in control plants grown on Earth during the same period of time.

Buta, who is with the Horticultural Crops Laboratory in Beltsville, Maryland, helped analyze indole-3-acetic acid (IAA) and abscisic acid (ABA), both major plant growth hormones.

"These hormones were selected for comparison because they are thought to be sensitive indicators of the plants' physiological status," he says.

Robert S. Bandurski and Aga Schulze, Michigan State University botanists, designed the shuttle experiment to test plant growth reaction to the lack of gravity.

"Although the plants were physiologically the same, they looked quite different," Bandurski points out.

Instead of growing "straight up," seeds grew sideways in space.

In the absence of gravity, the plants became disoriented, not knowing which way was "up."

"The roots didn't know to grow down, and the shoots tied themselves into knots because they didn't know where to go," he explains.

On the Atlantis, 104 corn seeds were placed in aluminum canisters that allowed air to enter but admitted no light, since gravity was the only factor being studied. While still in flight, astronauts froze the canisters of plants to preserve any changes that might have occurred in space. The freezing also prevented reversal of any possible changes from the effects of gravity, on return to Earth.

Although the problem of plant growth orientation must be addressed, the 5-day experiment showed that growing food in a space station isn't just science fiction.—By **Doris Stanley**, ARS.

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Understanding Aluminum Toxicity in Plants

Leon Kochian spends his days looking a gift horse in the mouth.

For years, farmers have struggled with acid soils in which overabundance of soluble aluminum has spelled death to crops. And when a particular type of maize or sorghum or wheat seemed able to tolerate the excess aluminum, the farmers gratefully accepted that crop as a gift of nature and didn't ask a lot of seemingly unanswerable questions.

Kochian, a plant physiologist at the U.S. Plant, Soil, and Nutrition Laboratory at Ithaca, New York, on the other hand, has enough questions to make up for everyone else. He wants to know why certain plants can put up with aluminum toxicity and to find out what's happening to the ones that can't. The answers will be important to a lot of people.

"Up to 70 percent of the world's potentially arable soils are acidic, including regions in the eastern United States and large areas in Asia, Africa, and South America," says Kochian. "Aluminum toxicity is the primary problem limiting agricultural production in these acid soils."

That's because aluminum is one of the most prevalent minerals in the Earth's crust. High acidity in soil can render that aluminum soluble—forming with water a potion that is deadly to growing plants.

While lime can be added to soil to neutralize some of the troublemaking acid, that's a "luxury" many Third World farmers can neither obtain nor afford. Even when lime is a feasible expenditure, it's hard to place deep in the soil. So excess aluminum might still lurk below the limed zone, down where thirsty roots wander in the summer.

It's those groping roots that engross Kochian and his coworkers these days. Their studies have revealed the root tip is the plant's Achilles' heel when it comes to aluminum.

"In experiments, we exposed the entire root system—except the tip—to a solution containing a toxic level of aluminum, and the roots grew just fine," Kochian recalls. "But when we exposed just the root tip to the same solution, growth was inhibited in about 2 hours."

In comparisons of aluminum-tolerant and nontolerant plants, uptake into the root tip of elements such as potassium and chlorine was not hindered in either group of plants when aluminum levels were high. But calcium uptake was a different story.

"We found aluminum inhibits calcium uptake almost immediately in aluminum-sensitive plants," Kochian notes. "But we saw a much smaller effect on calcium uptake in aluminum-tolerant plants."

Calcium is an essential plant nutrient and plays an important role in regulating many diverse cell functions, Kochian adds.

"Our goal is to develop more aluminum-tolerant crop plants," he concludes. "As we learn what's happening in aluminum toxicity and find out what's different in the tolerant plants, we can better look for ways to develop or transfer that tolerance to other plants."—By **Sandy Miller Hays**, ARS.

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The publication mentioned in *Agricultural Research,* August 1992, page 9, "Changes in Vegetation and Land Use in Eastern Colorado, A Photographic Study, 1904-1986," (ARS-85, Sept. 1991) by William J. McGinnies, is still in print. Single free copies can be obtained from Charley E. Townsend, USDA-ARS, 1701 Center Ave., Ft. Collins, CO 80526. Phone (303) 498-4231, fax number (303) 482-2909.

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Just off press:

Fire Blight—Its Nature, Prevention, and Control; A Practical Guide to Integrated Disease Management

Published by the U.S. Department of Agriculture, Agricultural Research Service, this Agricultural Information Bulletin (AIB 631) was written by T. van der Zwet of the ARS Appalachian Fruit Research Station in Kearneysville, West Virginia, and S.V. Beer of the Department of Plant Pathology at Cornell University in Ithaca, New York.

Fire blight is a serious bacterial disease of apples, pears, quinces, and several plants in the rose family, including hawthorn, cotoneaster, firethorn (pyracantha), mountain ash, blackberry, and raspberry. Outbreaks of fire blight are usually most severe in areas with a warm, humid climate, especially when these conditions occur while the plant is blooming.

Meant especially for growers of apples and pears because many varieties and rootstocks of these fruits are very susceptible to fire blight, this publication is a practical guide to prevention, identification, and control of the disease.

While supplies last, copies may be obtained, at no cost, from the following: USDA-ARS-NAA, Appalachian Fruit Research Station, 45 Wiltshire Road, Kearneysville WV 25430; and, Department of Plant Pathology, Cornell University, Ithaca, NY 14853.

SCOTT BAUER